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PORTO RICO AGRICULTURAL EXPERIMENT STATION,
D. W. MAY, Agronomist in Charge,
Mayaguez, P. R.

Bulletin No. 21.

SOME PROFITABLE AND UNPROFITABLE COFFEE LANDS.

BY

T. B. McCLELLAND,
Assistant Horticulturist.

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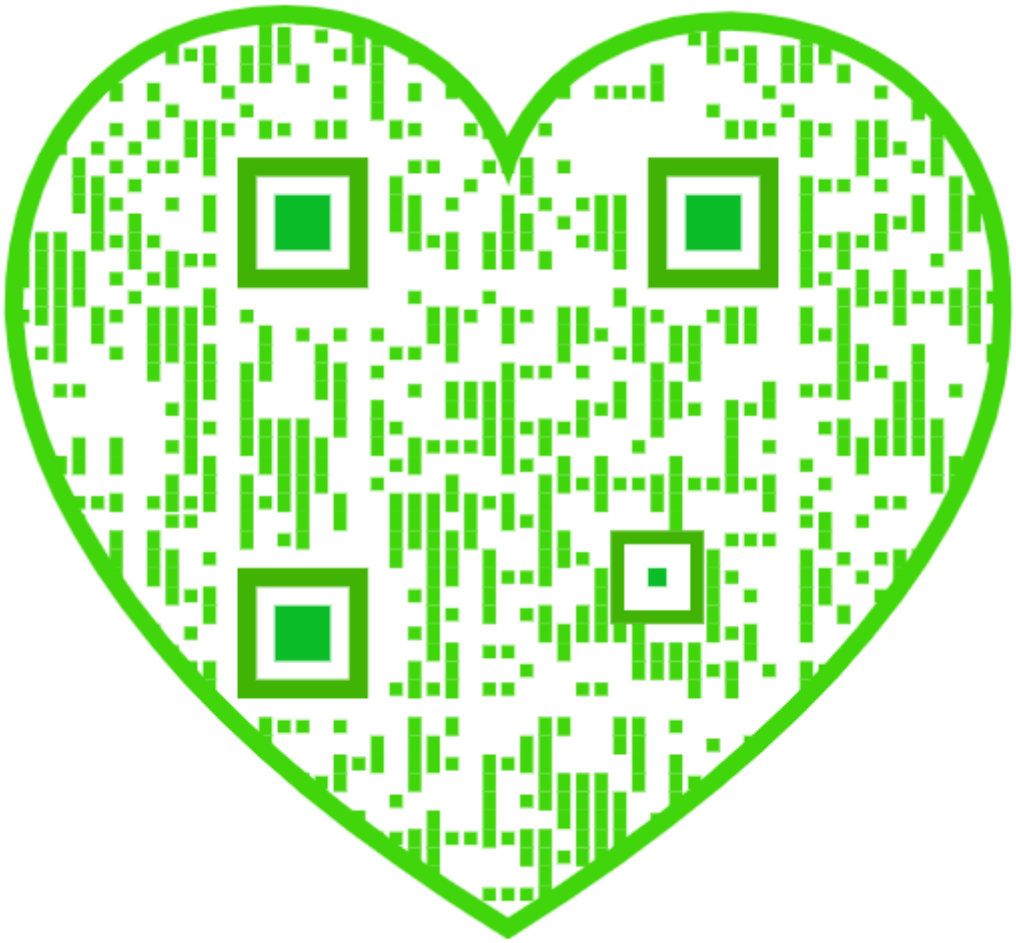

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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C TRUE, Director of the States Relations Service, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., February 19, 1916.

SIR: I have the honor to transmit herewith a manuscript by T. B. McClelland on Some Profitable and Unprofitable Coffee Lands. This manuscript, based upon studies of Porto Rican coffee soils extending over a number of years, shows that soils not well adapted to coffee culture have frequently been used for that purpose. Information is given which it is believed, will aid in the better selection of coffee land and so will reduce losses due to use of unprofitable soils. The discussion of the subject is timely and should prove valuable to the coffee industry, upon which a majority of the people of Porto Rico depend for their livelihood. I recommend that the manuscript be published as Bulletin 21 of this station.

Respectfully,

D. W. MAY,
Agronomist in Charge.

Dr. A. C. TRUE,
Director States Relations Service,
United States Department of Agriculture, Washington, D. C.

Recommended for publication.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

PROFITABLE AND UNPROFITABLE COFFEE LANDS

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INTRODUCTION.

The yields of coffee in Porto Rico as a whole are regrettably small. Estimating the local per capita consumption of coffee at the same rate as that of Cuba and adding this to the coffee exported would give an average annual production of about 316 pounds of cleaned coffee per acre for the 10-year period covered by the fiscal years 1905 to 1914.

For this small average yield many causes are to be found, working both singly and together. Coffee trees, even in a fertile soil, sometimes become unprofitable through the ravages of insect and fungus enemies, and the planter, considering his poor and sparsely foliated trees the result of a poor soil, treats his soil to remove an entirely unrelated trouble. In other cases, however, his unprofitable plantings may be the result of an uncongenial soil. Frequently soils not adapted to coffee have been planted to this crop, while soils better adapted to the purpose have been left unplanted.

Under favorable conditions a coffee tree is very productive. Any coffee planter can tell of plantings of limited extent which yield at the rate of from 1,000 to 2,000 pounds or more per acre. Occasionally a single tree may be seen which is producing, under ideal conditions, as much as 10 pounds of coffee. To grow each tree under ideal conditions is impossible, but where there is a choice of sites for new plantings, as is nearly always the case on Porto Rican coffee plantations, a knowledge of the suitability or unsuitability of different locations and the factors influencing them is necessary in making a selection.

A soil or location which is favorable for one crop is by no means necessarily favorable for others. Conditions which are well suited to sugar cane or to pineapples may be entirely unsuited to coffee. For each crop the particular conditions which are essential to the best development of that crop must be sought.

The report given in the following pages of studies extending through a number of years deals with specific examples of a definite

condition, as typified by many of the low hills extending from the west coast of the island well back into the interior. These hills produce on the lower slopes nearest the valley bottoms a vigorous and thrifty growth of coffee, the vigor diminishing with the rise of the land until the upper slopes near the ridges produce only a poor and meager growth. This condition is related to the topography of the immediate vicinity and not to the elevation above sea level, it being generally conceded that in this latitude coffee[1] does better at elevations of 1,000 or more feet than at sea level. This relation between growth and position on the slope is by no means universal, as in the higher coffee lands many of the mountains are productive to the top, but it is a condition so frequently encountered as to demand special attention and investigation. The land, which is unprofitable for coffee, is in no sense barren, as it is or has been covered by a very mixed vegetation, including trees of fair or large size. Frequently it is virgin soil, and so can not be considered as "tired." It is often much like the subsoil in appearance and is almost entirely lacking in humus. Coffee plantings on the station grounds clearly demonstrate the difference in growth made by coffee on the upper and lower slopes of hills of this type.

SPECIFIC INSTANCES OF PROFITABLE AND UNPROFITABLE COFFEE LANDS.

MOCHA COFFEE PLANTING.

A hill quite typical of the land frequently planted to coffee, rising at an angle of 25° to 30°, and in apparently virgin forest, there being no indications of previous planting, was set in September, 1909, with 293 young plants of Mocha coffee 12 to 18 inches high, in 14 rows of 20 to 22 trees each, the rows running down the slope. The trees planted nearest the valley bottom are about 35 feet from a brook, the trees on the highest land being back some 200 feet.

For convenience in referring to the trees on higher and lower ground the planting will be considered as divided into seven sections running at right angles to the rows, the usual depth of a section being 3 trees. Section 1 consists of the upper ends of the rows while section 7 is nearest the valley bottom. The planting was divided into two parts, division 1 consisting of rows 1 to 7, and division 2, of rows 8 to 14.

To test the practical value of cultivation and manuring in each division 2 rows were cultivated and 2 rows were manured at frequent intervals, the other 3 rows being left as a check. The cultivation was done with a spading fork or a pronged hoe and covered an area sufficient for an ample root extension. Cultivation was given

[1] Coffee in this bulletin refers only to *Coffea arabica*.

approximately every other month, the trees being cultivated 27 times from March, 1910, to the time at which the last reported measurements were made, November, 1914.

Beginning with the spring of 1910, the manured trees received stable manure twice yearly. The first year the manure was put in trenches above the trees, each application being at the rate of 5 tons per acre. After that it was spread as a surface mulch around the tree, each tree receiving a 5-gallon measure of manure at each application.

To prevent loss of soil through the frequent cultivation of certain rows and to furnish a level surface from which the manure would not be washed away by the heavy rains, each of the cultivated and the manured trees had an individual terrace or planting table made for it by cutting away the soil at the upper side and placing it at the lower side of the tree, thus making a small, level platform.

The check rows were given no treatment other than that necessary to prevent growth of weeds and pruning, which all received.

By November, 1910—that is, within a year from setting—the three upper sections had lost 15 trees, the other sections 3 only. By November, 1911, 31 trees more had died in the three upper sections and only 2 more in the four lower sections, making a total of 46 trees lost from the upper slope and 5 from the lower planting. This indicated very clearly the unsuitability of this upper slope for coffee growing.

In 1911 the different treatments showed no effect on the percentage of trees bearing. Of the check trees 29.3 per cent were in bearing, while of the manured trees 30.2 per cent and of the cultivated 30.7 per cent were producing.

In 1912 the percentages of trees bearing were as follows: Check, 86.0 per cent; manured, 67.2 per cent; and cultivated, 71.2 per cent. The average yield per tree, including nonproducing trees, was for the check 0.21 quart, for the manured 0.40 quart, and for the cultivated trees 0.18 quart of fresh coffee cherries. These yields were all very small, but the manure here seemed effective in increasing the yield.

The most striking point, however, about this crop was the relative position of bearing and nonbearing trees. Of 71 trees still living in the three upper sections, only 30 trees, or about 42 per cent, produced coffee, while of the 153 trees surviving in the four lower sections, 141 trees, or about 92 per cent, bore coffee. This, again, would indicate the unsuitability of the upper slope.

In 1913 the average yield per tree was for the check 0.93 quart, for the manured 1.07 quarts, and for the cultivated trees 0.66 quart of coffee cherries. In 1914 the average was for the check 0.37 quart, for the manured 0.50 quart, and for the cultivated trees 0.45 quart.

In each crop the manure has seemed effective in producing an increase in yield. It has not, however, overcome the unfavorable and infertile condition of the land near the hilltop. This is clearly demonstrated by the growth of the coffee trees.

Table I gives the average height per tree with the rows grouped according to treatment given:

TABLE I.—*Average height of coffee trees set September, 1909.*

Date.	Check rows.	Manured rows.	Cultivated rows.	Date.	Check rows.	Manured rows.	Cultivated rows.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
November, 1911....	35.4	35.5	35.0	November, 1913....	68.7	66.6	68.0
November, 1912....	51.4	51.9	51.2	November, 1914....	82.8	79.3	83.0

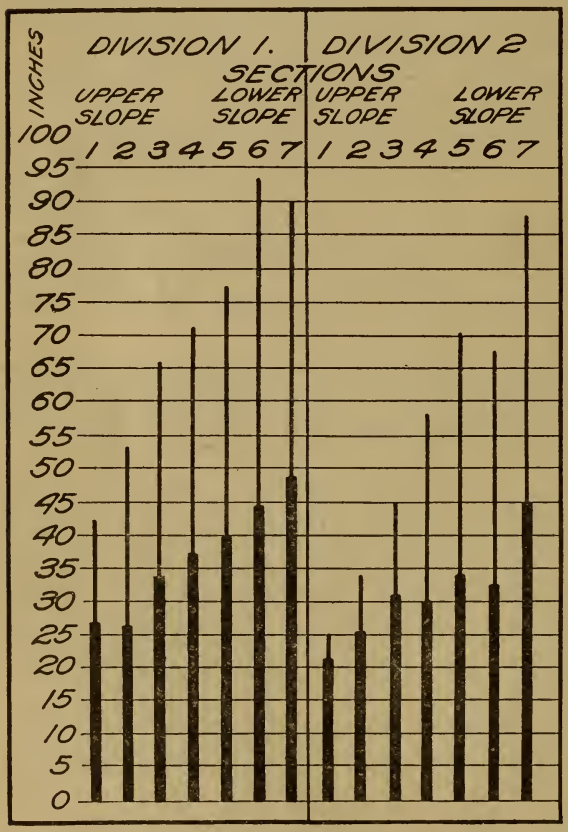

FIG. 1.—Growth of Mocha coffee trees as affected by position on slope. The heavy lines show growth to November, 1911; the light lines to November, 1913. The elevation declines from left to right in each division.

Such uniformity of growth as this would be surprising in plats which had received the same treatment, and is quite remarkable for trees receiving such diverse treatments.

When the trees are grouped by sections with reference to elevation, a striking difference in growth is seen between those near the hilltop and those near the valley bottom (Pl. I, figs. 1 and 2). In the following diagram the trees are grouped in two divisions, subdivided into sections, the first division of rows 1 to 7 taken as a unit, the other of rows 8 to 14, the elevation declining in each unit from left to right.

The measurements show the thrifty growth on the lower land in strong contrast with the feeble growth made on the upper slope. The slightly depressed growth in division 2, section 6, is easily

FIG. 1.—MOCHA COFFEE ON UPPER SLOPE, CHECK TREES (DIVISION 2, SECTION 3).

FIG. 2.—MOCHA COFFEE ON LOWER SLOPE, CHECK TREES (DIVISION 2, SECTION 7).

Fig. 1.—Columnaris Coffee Above Footpath.

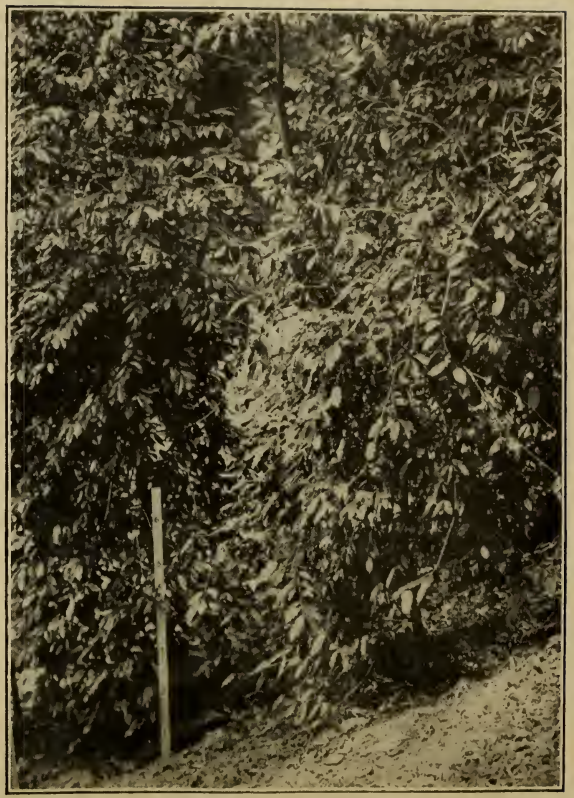

Fig. 2.—Columnaris Coffee Below Footpath.

accounted for by the close proximity of a giant "algarobo" tree (*Hymenæa courbaril*).

Figure 2 shows the height of the trees in November, 1914, plotted as a curve for each treatment given, divisions 1 and 2 being taken together.

These curves fail to show any very material increase in growth produced by cultivation or manuring. They show, however, under all treatments a favorable condition for growth near the valley bottom and on the lower slope, and uncongenial surroundings above. Such growth demonstrates that all available space on the lower slope or near the brook should be utilized for coffee plantings, and that expensive treatments, such as frequent cultivation and frequent applications of manure on unfavorable upper slopes will result in financial loss.

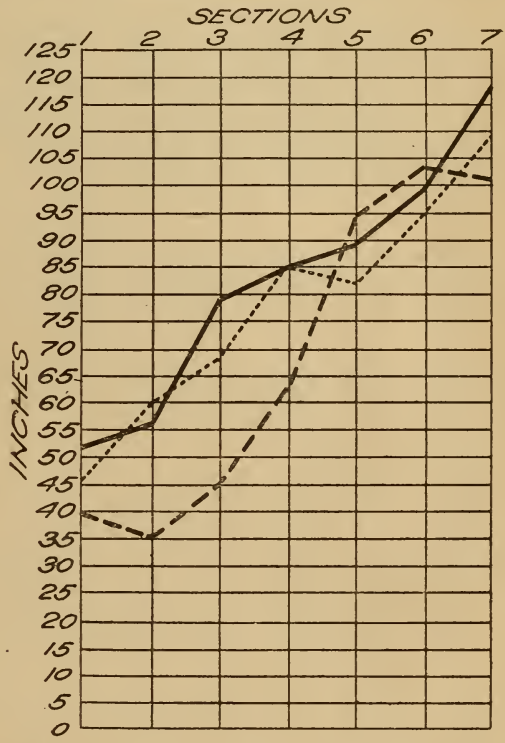

FIG. 2.—Growth of Mocha coffee trees as affected by cultivation and manuring. The unbroken line shows the height of the cultivated trees; the broken line, that of the manured trees; and the dotted line, that of the check. Elevation same as in previous figure.

COLUMNARIS COFFEE PLANTING.

Another example of the great difference in productivity of closely adjacent parcels of land in relation to their position on the slope is shown in a planting of Columnaris coffee set in 1909 on the slope of a hill at some distance from the Mocha coffee planting described above. The inclination of the slope in this case is much the same as in the other. During the rainy season a brook runs at the lower side of the planting. About half way up, 40 to 50 feet above the brook, a footpath divides the planting into two sections, one of 65 trees above the path, and the other of 61 trees below it. (Pl. II, figs. 1 and 2.)

In 1914, the crop from above and below the footpath was picked separately. Of the 61 trees below the path all produced coffee, while

12 above did not. The yield from the trees below the path was 320.7 quarts of coffee cherries, an average of 5.26 quarts per tree. From all trees above the path the yield was only 79 quarts, an average of 1.22 quarts per tree. This means that, on the whole, one tree below the path produced more coffee than four above it, and was accordingly for that crop more than four times as valuable, since one tree is less expensive to care for than four.

GUADELOUPE COFFEE PLANTING.

As a further demonstration of the greater productiveness of the land near the valley bottom, another planting in which the rows of trees ran down one slope and up the opposite may be cited. These trees are from seed obtained from Guadeloupe and are identical in appearance with the Porto Rican variety. The trees were set about 8 feet apart. They were all seedlings of the same age and were less

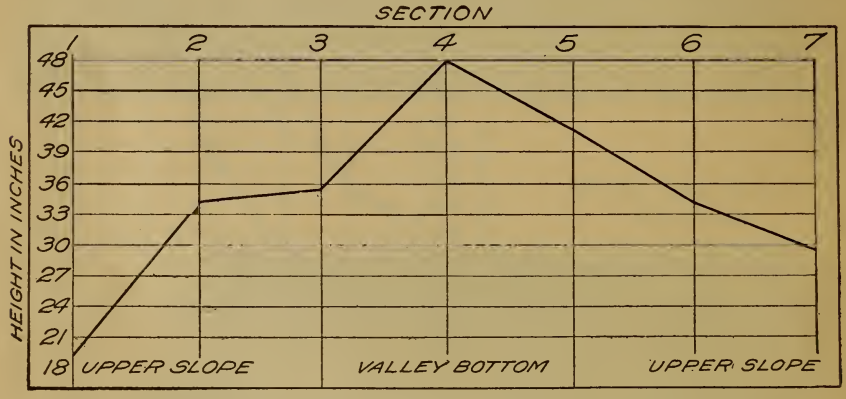

FIG. 3.—Growth of Guadeloupe coffee trees as affected by position on slope.

than 3 years old at the time the measurements were taken. The diagram shown in figure 3 is based on data from 6 rows taken as a unit, each row running down one side of the valley and up the opposite. Each row had been set with 21 trees. For convenience of reference, the rows may be thought of as divided into 7 sections, each 3 trees deep. Thus a point in the diagram is determined by 18 trees except where trees have died. The middle section, section 4, contains trees on both sides of the valley bottom, through which flows a small stream in wet weather. Sections 1 and 7 contain the trees on the highest land. The slope of the valley sides is much the same as that of the two plantings previously discussed. The diagram (fig. 3) shows that the growth of the trees is correlated with the lay of the land, being thrifty and strong in the valley bottom, but decreasing steadily with the rise of the land.

INVESTIGATIONS OF THE SOILS.

Examinations of the particular soils on which the above plantings were made show browner soils on the lower slopes and redder soils above, indicating the presence of more organic matter in the soils of the lower slopes, which constantly receive leaves, loose surface soil, and washings from above. In the Mocha planting, on both upper and lower slopes, the layer of darker surface soil is 7 to 8 inches deep, with a redder soil under this. The soil of the lower slope, however, is much darker than that of the upper slope. In the Columnaris planting, the soil of the upper slope is very red and any line of division between surface soil and subsoil is difficult to see, though the top 3 inches may be slightly darker. The lower part planted to Columnaris trees has 12 to 15 inches of brownish-red soil underlain by a slightly redder subsoil. In the Guadeloupe planting, the upper slopes have 3 to 4 inches of soil over a very slightly redder subsoil. The section in the valley bottom has a browner soil about 7 inches deep with a redder subsoil.

As a general thing the most apparent differences between the upper and the lower slope are in color and depth of soil, the lower slope having a much richer and deeper soil layer.

In each of the cases noted, the land near the valley bottom has shown itself thoroughly adapted to coffee, while in none of them has the land farther up the slope shown itself at all comparable to the lower land.

In the first planting discussed, cultivation and manuring failed to overcome the unfavorable conditions of the upper slope.

In the Columnaris coffee planting, in plats crossing both sections, leguminous cover crops have been planted one to several times each year since 1910, but a very satisfactory stand has never been obtained, probably owing to the shade, as cover crops were planted which were known to do well in similar soils when unshaded. The average yield per tree of the cover crop and check plats on the poor soil above the path for the combined 1914 and 1915 crops was identical. The establishing of a heavy cover crop as a means of improving such lands, shaded by both the coffee and the coffee-shade trees, is a difficult proposition.

EXPERIMENTS IN LIMING.

That liming is not the solution of the problem of lower productions on the upper slopes was shown by some experiments begun in 1910.

Figure 4 shows the height in inches of some limed and unlimed coffee trees four years after setting. Their height is very clearly governed principally by their position on the slope.

The curve at the left represents the growth of a planting originally of 57 trees set in four lines running up and down a sloping hillside. Two rows were left as the check. The trees of the other two rows were limed at the total rate of 6½ pounds of air-slaked lime each, receiving this in four applications with a year's interval between each application. To construct the curve the rows were considered as if divided into three sections, the first consisting of the trees on the lower slope, the second of those halfway up, and the third of the trees on the upper slope. The average height of the check trees was 57.7 inches, that of the limed trees 63.4 inches, a difference of less than 6 inches for four years' growth.

The curve at the right represents the height of trees of a planting made simultaneously with the one described above. The applications of the lime were made simultaneously with the preceding but in smaller amounts, a total of only 3½ pounds per tree. As this planting was made in a number of much shorter rows running up and down the hill, to construct the curve only the five upper rows running at right angles to the slopes were taken, each row determining a point in the diagram. In these five rows the check includes 22 trees and the limed rows 17 trees. Where the whole planting is considered the average height of the check trees was 50.1 inches and that of the limed trees 53.3 inches, a difference of 3.2 inches for four years' growth.

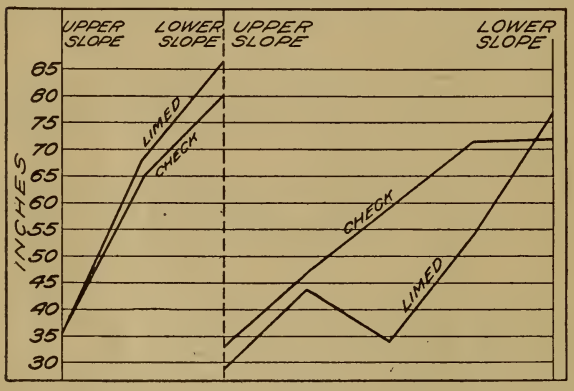

FIG. 4.—Growth of coffee as affected by liming and by position on slope.

In the first instance, before filling the planting hole with earth 1 pound of lime was scattered in it. In the second, one-half pound was scattered in the hole. The rest of the lime was all applied to the surface.

The results of this experiment indicate that the unproductiveness of the upper slopes can not be overcome by the application of lime, as some have thought and suggested.

MOISTURE CONTENT OF THE SOILS IN A DRY SEASON.

To investigate the relation of the moisture content to productiveness, determinations of the soil moisture were made throughout

the dry season of 1914–15 in the upper and lower portions of the areas planted to Mocha and Guadeloupe coffee.

Approved methods of soil sampling and drying were followed. The soil samples were taken to a depth of 12 inches by means of a small brass tube cutting a column of soil three-fourths inch in diameter. After thorough mixing, 100 grams of each sample was dried in an oven to a constant weight.

The soil moisture, expressed as percentage of the original weight of the sample as determined by the loss in weight in drying, and the dates on which the samples were collected are shown in Table II.

TABLE II.—*Moisture content of soils of Mocha and Guadeloupe coffee plantings throughout a dry season.*

Date.	Lower Mocha.	Upper Mocha.	Lower Guadeloupe.	Upper Guadeloupe.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Nov. 25, 1914	28.0	26.9	30.4	31.9
Dec. 9, 1914	29.8	29.4	30.5	32.5
Dec. 23, 1914	30.4	29.3	31.4	33.1
Dec. 30, 1914	29.3	28.7	30.9	30.1
Jan. 6, 1915	27.6	26.8	29.2	30.7
Jan. 13, 1915	27.5	26.5	27.7	28.7
Jan. 20, 1915	26.2	26.4	27.3	28.1
Jan. 27, 1915	25.1	26.2	27.7	27.0
Feb. 3, 1915	28.2	26.2	28.6	29.9
Feb. 10, 1915	26.1	25.1	28.8	27.4
Feb. 17, 1915	24.3	25.4	27.4	25.9
Feb. 24, 1915	24.2	24.8	26.0	25.5
Mar. 3, 1915	23.6	24.4	25.1	25.9
Mar. 10, 1915	24.7	24.1	25.7	25.2
Mar. 17, 1915	23.8	23.9	26.9	23.9
Mar. 24, 1915	23.2	22.7	25.1	23.7
Mar. 31, 1915	20.8	22.0	23.7	23.2
Apr. 7, 1915	27.9	26.9	28.8	29.7
Total	470.7	465.7	501.2	502.4
Average moisture content	26.2	25.9	27.8	27.9

In accordance with the method described in a bulletin of this department,[1] a chart was made showing the seasonal variations in the soil-moisture content of the upper and lower slopes of the Mocha and Guadeloupe plantings. (See fig. 5.)

The rainfall recorded was as follows: October, 12.86 inches; November, 2.39 inches; December, 6.82 inches; January, 0.60 inch; February, 0.12 inch; March, 0.48 inch. The drought was broken by 3.92 inches of rain falling the first week of April.

A careful examination of the chart shows the soils on the same slope to be surprisingly alike in their moisture content. That the Guadeloupe soils contained more moisture than the Mocha soils is explained by the fact that the former slope has a northern exposure and so is more protected from the sun than the latter, which faces the south. In several instances in both plantings the curves representing the moisture content of the upper and lower slope intersect, but in no instance do the curves of the separate plantings touch.

[1] U. S. Dept. Agr., Div. Agr. Soils Bul. 4 (1896).

If the moisture content were the limiting factor, the curve representing the moisture of the lower slope would not be so intertwined in each instance with that of the upper slope, and where the daily variation is so small, a much closer relationship would be seen between the curves of the two upper or between those of the two lower slopes.

The data furnished in the table show an average difference in moisture content between soils of the same hillside of 0.1 per cent in one instance and 0.3 per cent in the other. In the Guadeloupe planting, where the samples were taken from more closely adjacent locations, the difference was less than in the Mocha planting, where the plats were more widely separated. In the former, the soil of the upper slope showed on the whole a slightly greater moisture content, while in the latter instance the reverse was true. Where the moisture content of the soil is considered to the depth of a foot, the

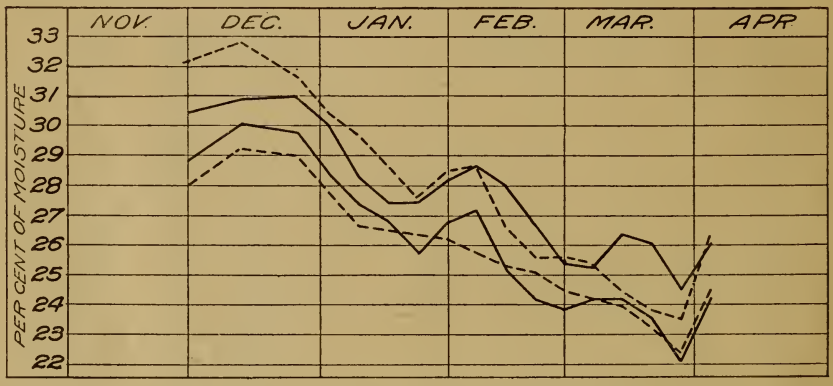

FIG. 5.—Soil moisture content of Mocha and Guadeloupe plantings. The two upper lines are of the Guadeloupe planting; the two lower, of the Mocha. Dotted lines represent upper slope; solid lines, lower slope.

difference in moisture content between the soils of the upper and lower slopes is seen to be so slight as definitely to show that some other factor was responsible for the pronounced differences in growth as shown in these two plantings.

This conclusion is borne out by the results of a series of pot tests. Forty-eight 6-inch cement tubes were filled with soil from the upper and lower Mocha and Guadelope slopes, 12 with soil from each location. The soil was dug to a spade's depth and thoroughly mixed. Coffee seed from a single tree were planted in the pots and all received the same treatment for about three months, when nearly all had expanded their cotyledons. Of each lot 3 were then watered once, 3 twice, 3 four times, and 3 six times a week, at each watering all pots receiving a uniform amount of water. The measure of water was varied from week to week in order to keep the most frequently watered pots as near saturation as possible and yet avoid an accu-

mulation of water in the tin holder in which each pot sat. At 7½ months from planting, while measurements showed that growth was in proportion to the amount of water supplied, they also showed marked variations on the different soils, the average growth in the soil from the lower Mocha slope being 7.4 inches as compared with 5.6 inches in that from the upper slope. The average growth on the soil from the lower Guadeloupe slope was 6.6 inches as against 5 inches in that from the upper slope.

DISCUSSION.

On every large coffee plantation marked differences are seen in the productiveness of different tracts.

A type of hill frequently met with in the district extending from the west coast of Porto Rico well back into the interior is one which produces vigorous and prolific coffee trees on the lower slope, but near the hilltop only trees of poor growth giving meager yields.

Studies were undertaken to determine, if possible, the cause of the poor growth on the upper slopes. This had been attributed to various causes, among others, a need of lime to correct the soil acidity, and a difference in moisture content between this soil and that of the more productive lower slope.

The experiments with lime showed that liming was not the solution of the difficulty.

Determinations, throughout the dry season, of the moisture content of profitable and unprofitable soils of the same hill indicated that the pronounced differences in growth on the upper and lower slopes could not be attributed to a difference in moisture content, the greatest average difference in moisture content of soils of the upper and lower slopes of the same hillside being only 0.3 per cent.

Frequent cultivations of the soil and moderately liberal applications of stable manure twice yearly, continued since March, 1910, to the present time, have each failed to produce a vigorous growth on the upper slope.

The soil of these unprofitable upper slopes frequently closely resembles the subsoil. On the lower slopes of the hills the soil layer has been deepened and enriched by deposits of soil washed from above for centuries. It is in these rich soils that coffee thrives and all of such land should be planted.

The poorer soils on which coffee makes only a weak growth should be devoted to pasture or forest or some other crop for which this land may be better adapted.

If such lands are to be used for coffee at all, large holes for future planting should be dug and left open until they can be filled with leaves, soil washings, stable manure, coffee pulp, or any organic material which, on decaying, will enrich the soil.

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